Transportation Applications for Solid Oxide Fuel Cells - Auxiliary Power

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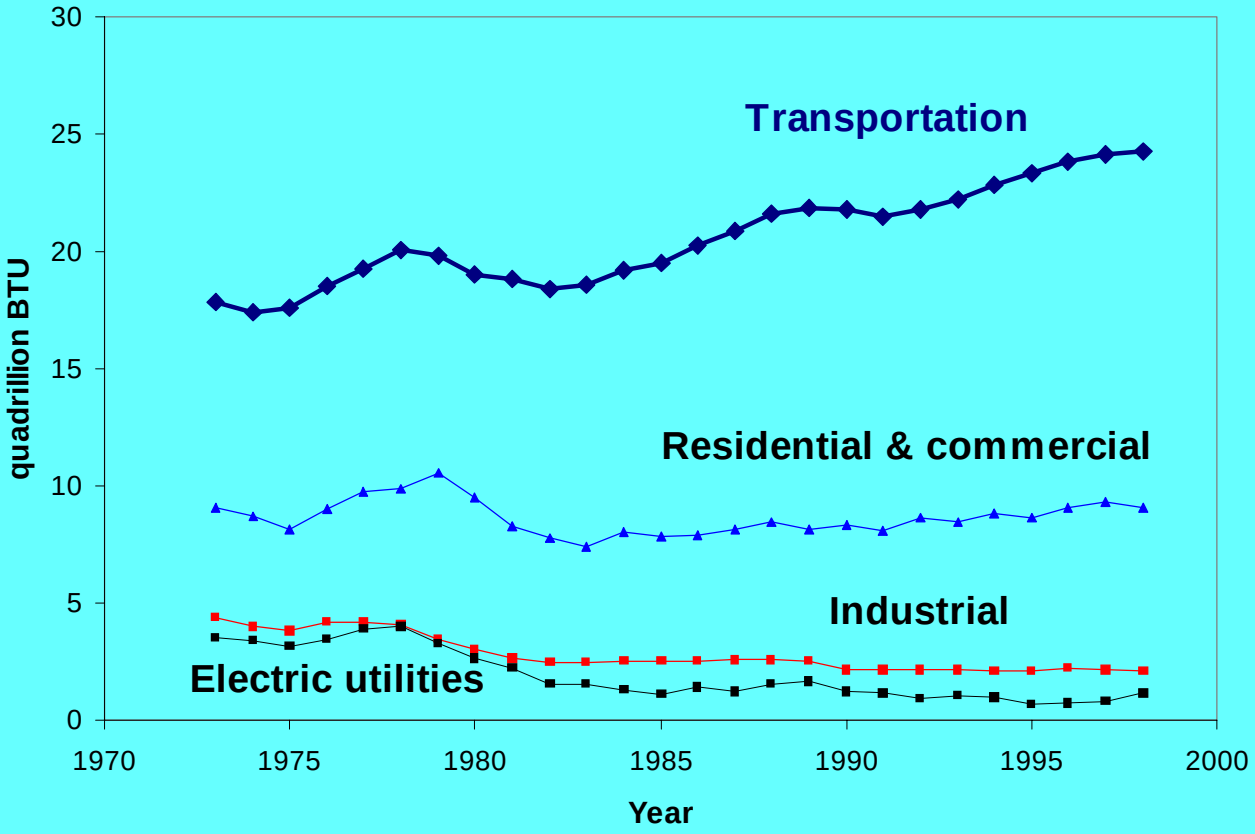
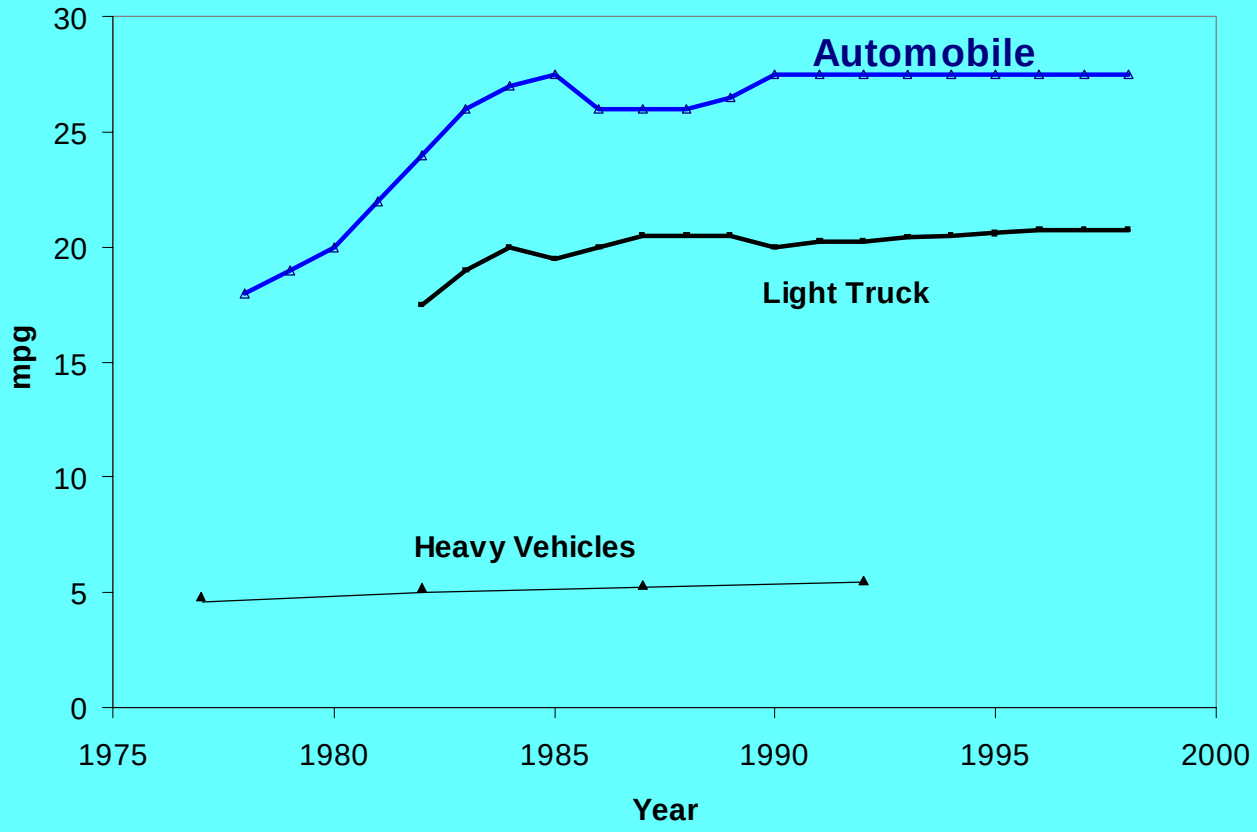
Consumption of Petroleum by End-Use Sector, 1973-1998



- Transportation is major petroleum end-user
  - more people
  - more vehicles

Source: Transportation Energy Data Book: Edition 19

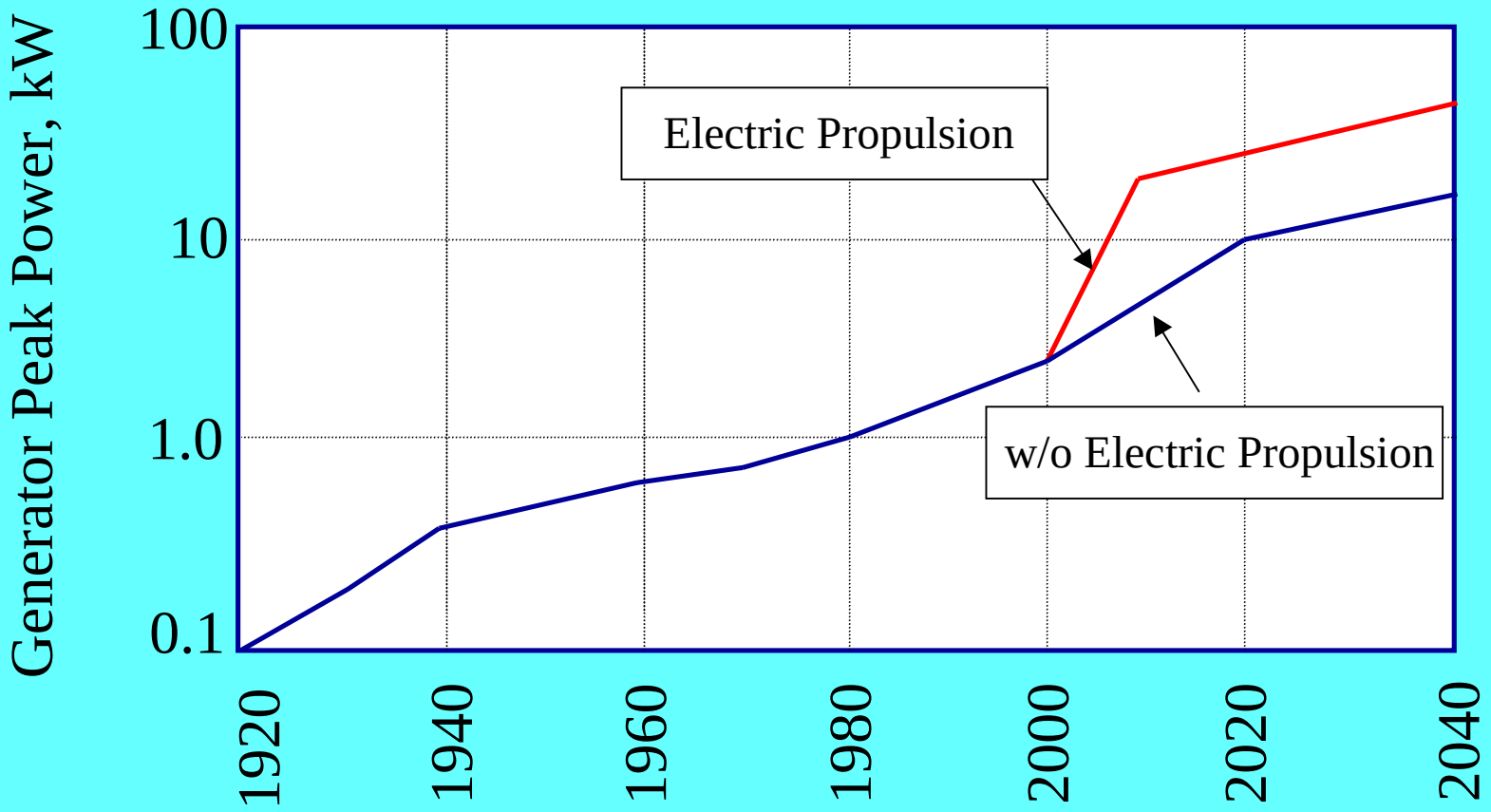
Transportation Fuel Economy



- Significant increase in overall vehicle efficiency has been realized:
  - more efficient engines
  - lightweight vehicle

Source: Transportation Energy Data Book: Edition 19

Automotive:
Increasing Electrical Power Requirements



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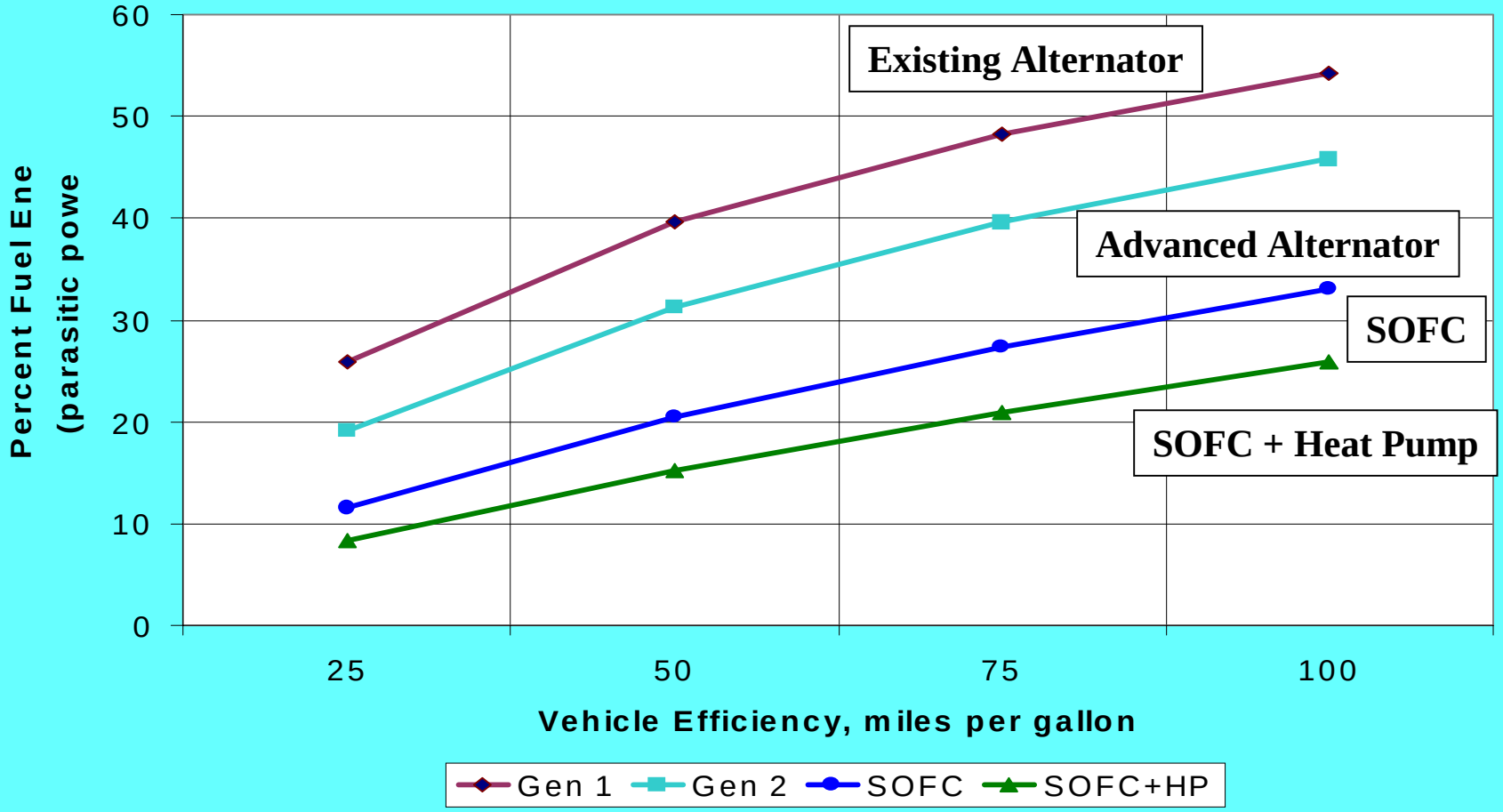
Automotive Auxiliary Power Market Drivers

Peak Power Requirements	kW
Electric suspension	12.0
Heated windshield	2.5
Electric valve control	2.4
Electric power steering	1.3
Anti-lock brakes systems	0.67
Catalyst Heater	0.6
Diesel direct Injection	0.47
Electric coolant pump	0.3
Compartment Fan	0.3
Total Expanding Demand	20.5 kW

5 kW Vehicle Auxiliary Power: Impact on Estimated Fuel Usage



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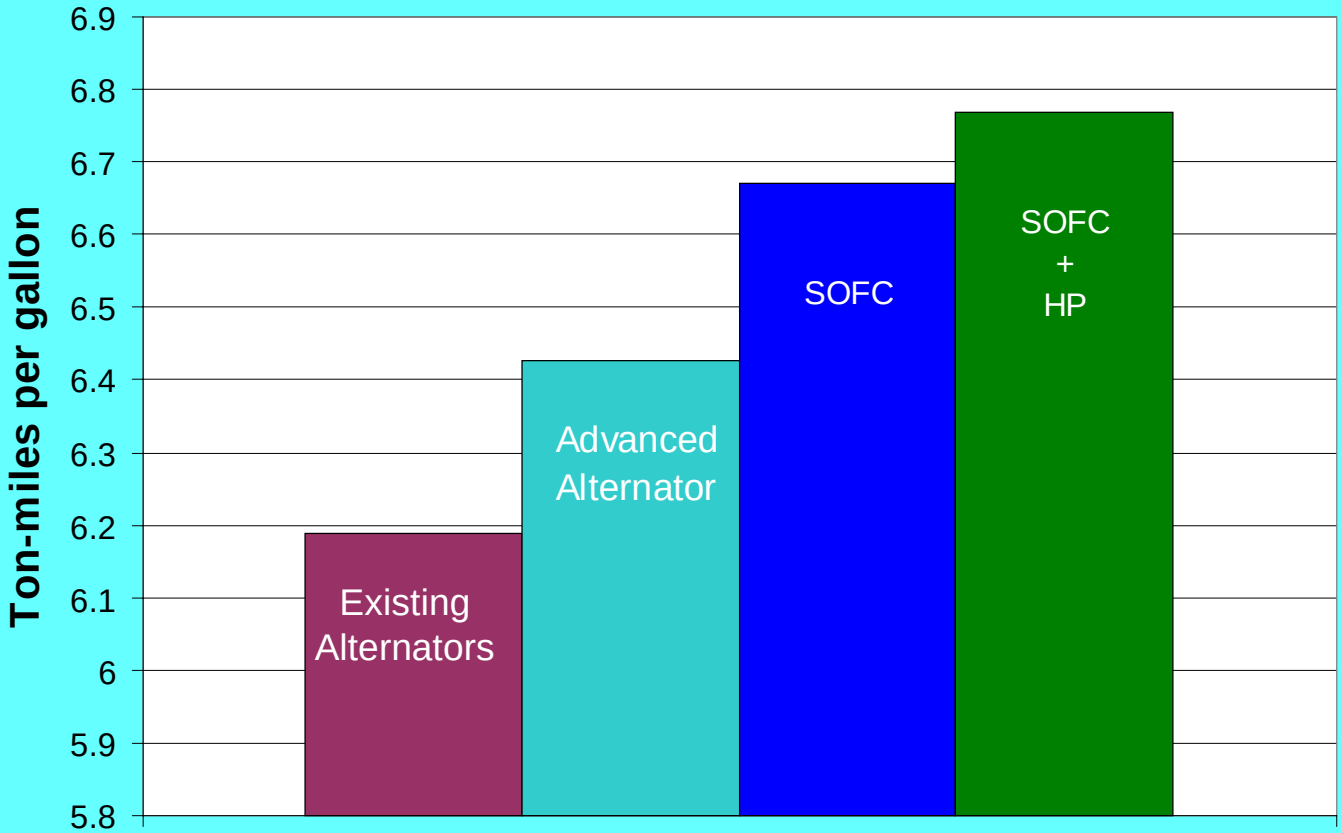
Auxiliary Power:
Ton-Mile Efficiency for Class 8 Truck



- Assume 5 kW continuous
- Assume a New York to Los Angeles, 60 mph
- 8 hours idle per day

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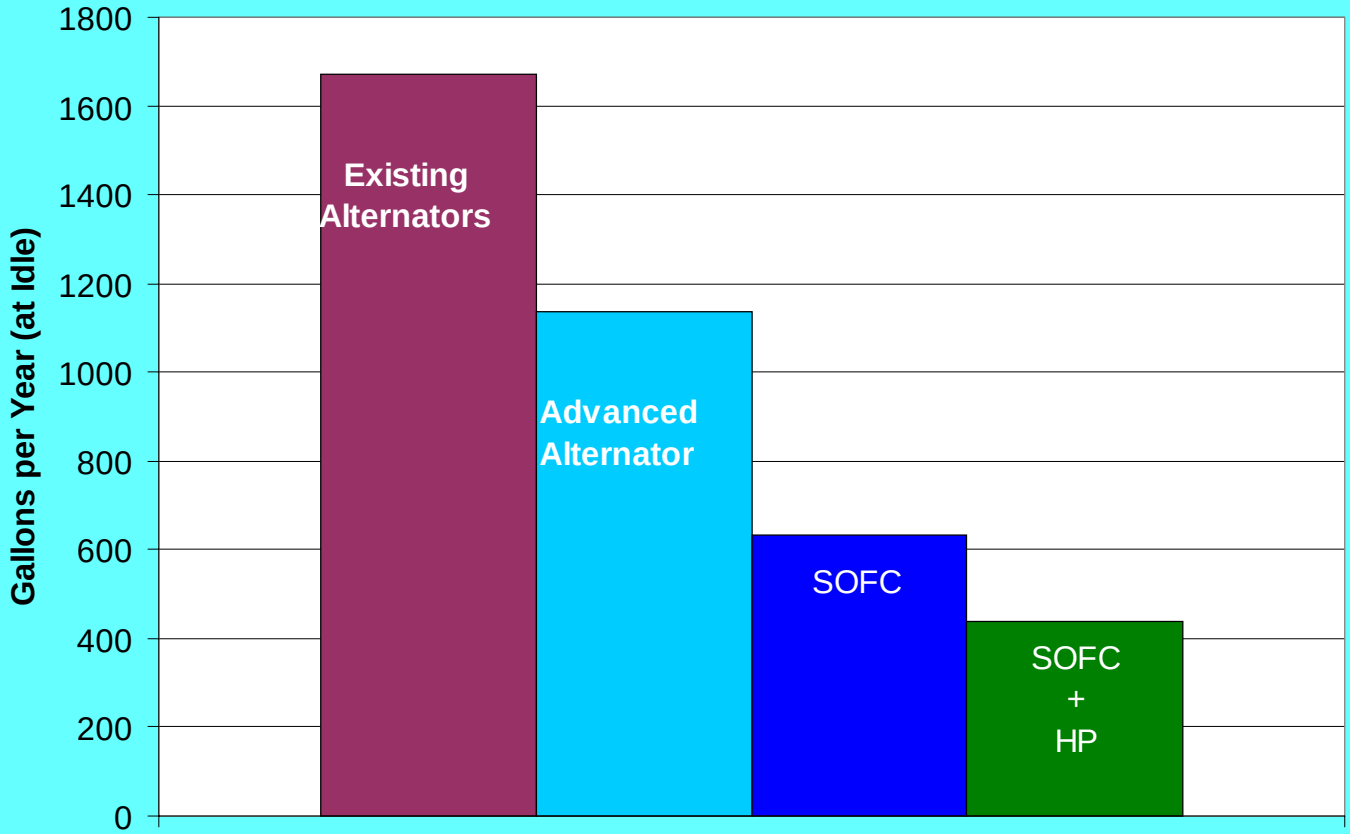
Estimated Idle Fuel Usage per Year, Class 8 Truck



- Significant fuel saving as APU efficiency increases
- 250 days in a year
- 8 hours idle per day

Mobile Electrical Power Generation

- **Engine/Generator**
  - Fuel Energy ->Mechanical Energy->Electrical Energy
    - Low overall efficiency = 12-17% peak, 5-7% idle
    - Inexpensive & reliable
- **Potential of Fuel Cells**
  - Fuel Energy -> Electrical Energy
    - High overall system efficiency > 40 %
    - Expensive, unreliable and (as yet) unproven
    - Environmentally friendly, reduced emissions
- **Fuel Cell Combined with Heat Pump**
    - Overall system efficiency >65%
    - Full independence of auxiliaries from engine operation
    - Minimizes emissions from auxiliaries

Advantages of Fuel Cell for Auxiliary Power

- Electricity without combustion
- Continuous production of electricity as long as fuel is supplied
- Environmentally clean
- High efficiency, > 60 % stack efficiencies
- Low Noise
- Modular and compact
- Potential for low cost

“Generic” Automotive APU Specification

Power	5 kW net
Rated voltage	42 Vdc
Mass Target	< 50 kg (0.1 kW/kg)
Volume Target	< 50 liter (0.1kW/liter)
Operation life	>5000 hrs
Cold Start Required	>3000 times
Warm Starts Required	SOFC < 10 minutes
Maintenance Required	>> 1000 hrs (30 ppm S)
Efficiency	> 40 %
Surface Temperature	< 45 degrees celsius

High Efficiency, Low Cost APU System

R&D Advances Required in:

- Solid Oxide Fuel Cell Stack
- Fuel Reformation
- Integrated Balance-of-Plant
- Thermal Control Subsystem
- Waste Energy Recovery Subsystem
- Power Electronics and Energy Storage Subsystem
- Entire System Cost must be driven down

Potential APU Markets

- Luxury Vehicles
- Recreational Vehicles
- Heavy Duty Trucks
- Short Haul Trucks
- Passenger Vehicles